

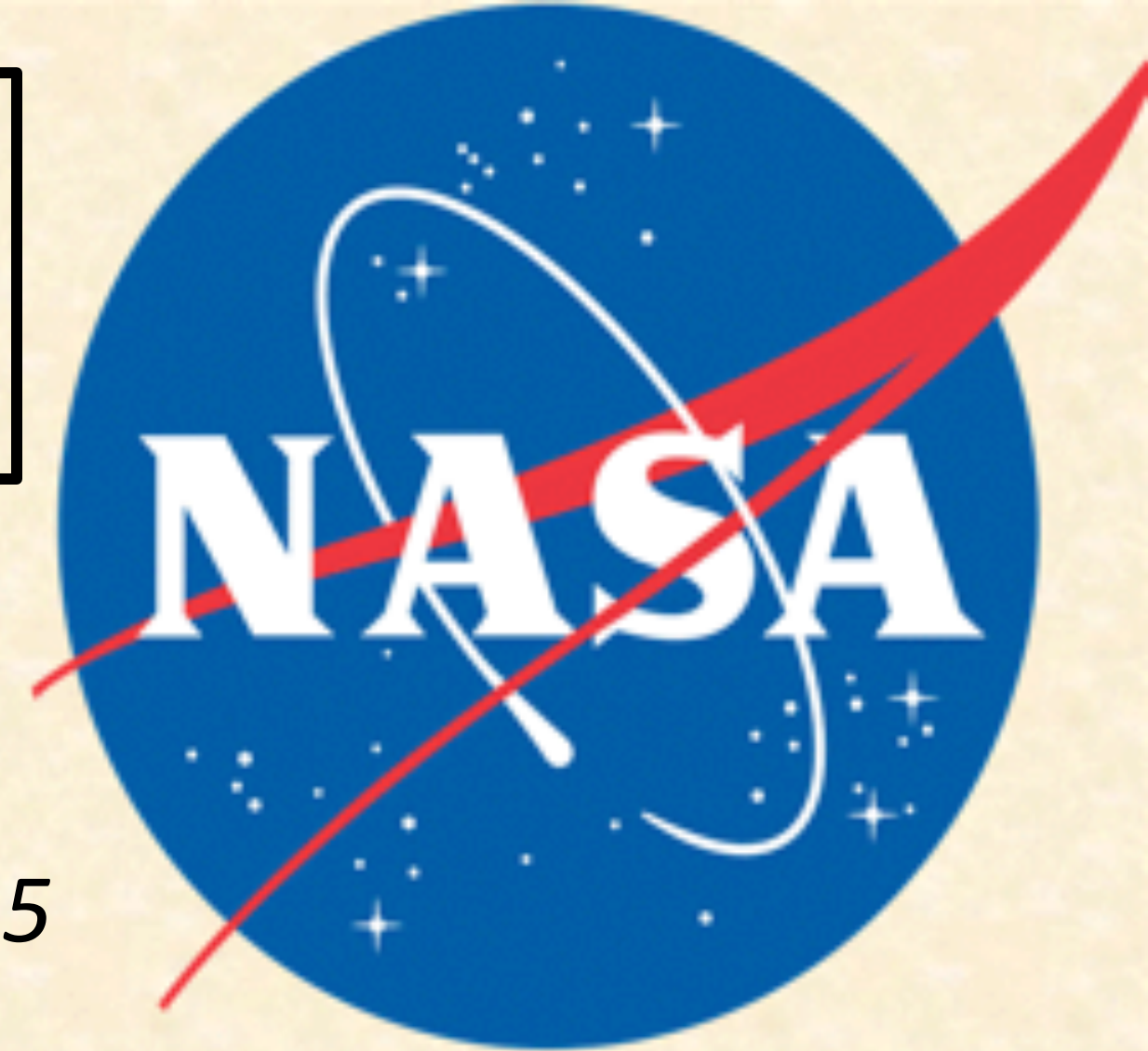
Modeling of Fragmentation of Asteroids

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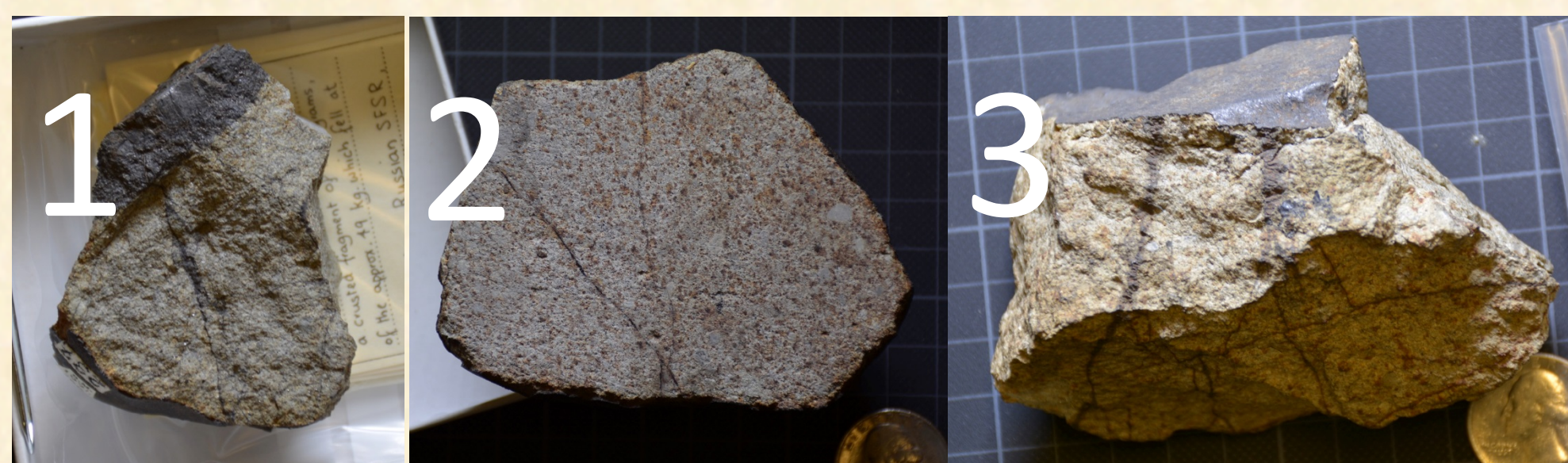
1st International Workshop on PHA Characterization, Atmospheric Entry and Risk Assessment
7 – 9 July 2015, NASA Ames Research Center, California

Objective

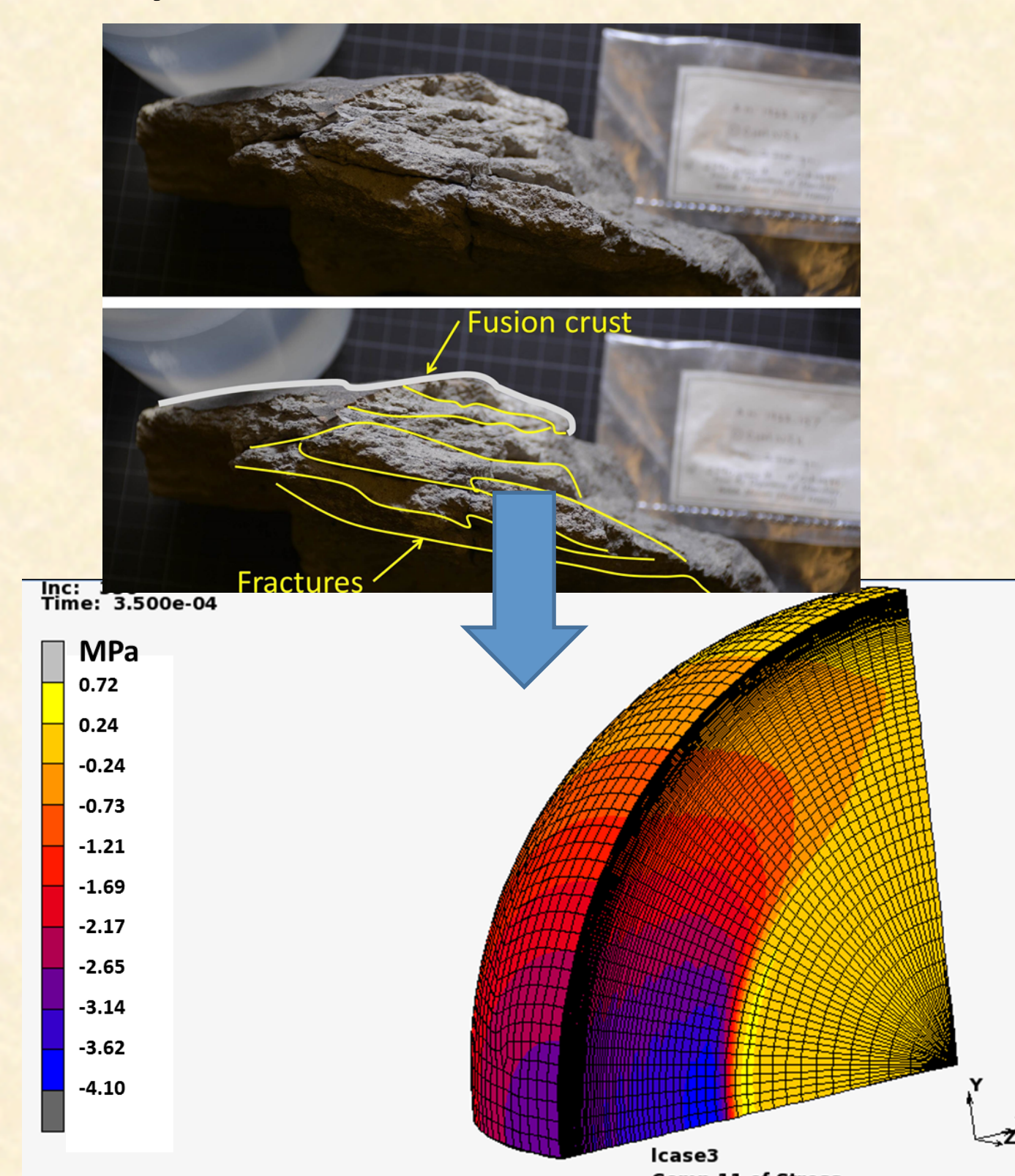
The objective of this study is to understand fragmentation and fracture of a given asteroid and mechanisms of break-up. The focus of the present work is to develop modeling techniques for stony asteroids in 10m-100m range to answer two questions: 1) What is the role of material makeup of an asteroid in the stress distribution? 2) How is stress distribution altered in the presence of pre-existing defects?

Characterization of Chondrites

- 1000s of ordinary chondrites characterized as representative of their stony asteroid parent bodies.
- The results indicate that when present most of the fractures are (1) in the form of thin veins and usually show no obvious orientation, (2) in some cases veins radiated from a point of weakness, (3) occasionally veins have chicken-wire or a brick-wall network (see poster Bryson, et al.)

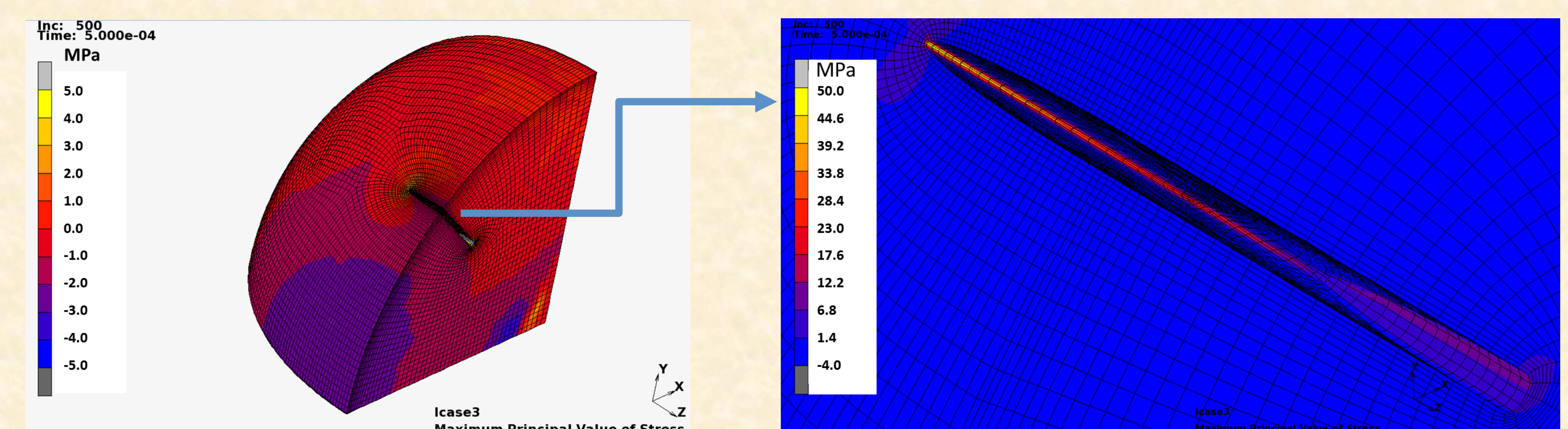


Preliminary analysis of a 10 meter diameter hemispherical body shows that the compressive stress concentration near the surface is similar to the rupture patterns observed in Ochansk meteorite



Influence of defects

A 1.5 meter long, 0.75 meter wide and .1 meter thick ellipsoidal cavity was modeled to investigate the changes in the stress distribution.



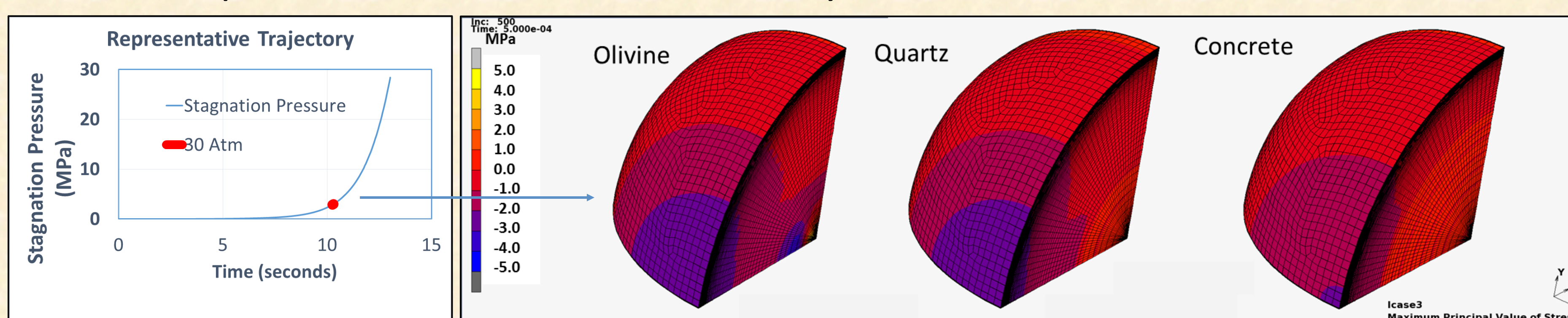
- The stress analysis shows a sudden jump in tensile stresses (50 MPa for Olivine), reaching the tensile strength, due to presence of the cavity.
- Significantly more amplification of stress is expected in the presence of sharper cracks.
- Unit cells representing the cracks on meteorites will be modeled next to understand the influence of pre-existing cracks.
- A scaling criterion will be developed next to model the asteroids with pre-existing defects.

Sensitivity Studies for Various Materials

- Considerable variations are observed in material properties of various classes of meteorites.
- In the absence of required material properties, esp. at elevated temperatures, sensitivity studies were performed for a number of possible material analogs, shown in Table 1.
- Analyses were performed at 30 bar stagnation pressure for a hemispherical idealized 10 meter diameter stony asteroid.
- A well-planned mechanical characterization effort is required for thermal-structural analysis.

Table 1: Properties of Material Analogs

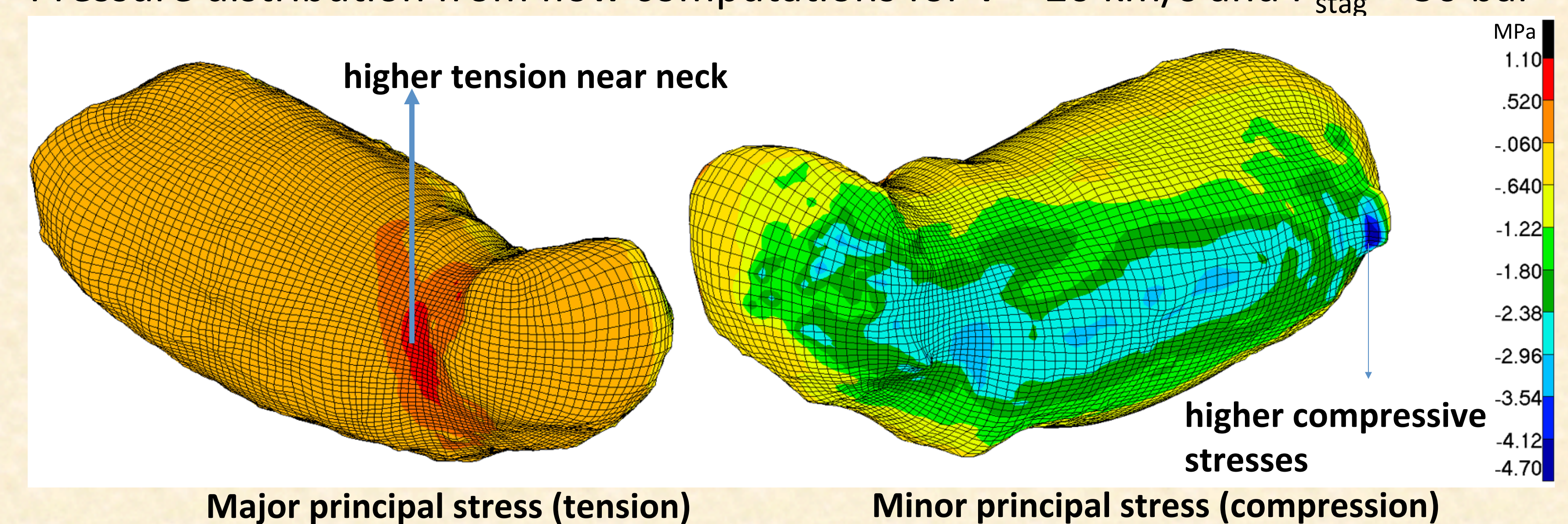
Property	Olivine	Quartz	Feldspar	Concrete
Density (g/cc)	3.28	2.20	2.74	3.2
Elasticity (GPa)	195	72	103	25
Poisson's Ratio (-)	0.25	0.17	0.30	0.25
Tensile Strength (MPa)	62	48	N/A	2.5-7.0
Compr. Strength (MPa)	400-500	1100	200-300	17-36



- Heat penetration into the structure was very small for thermal pulses. Therefore, only structural analyses were conducted.
- The requirements for quasi-static and dynamic finite element (FE) analyses are being determined.
- FE model development for more complex geometries and models with defects such as cracks and inclusions.

Modeling of Irregular Shaped Asteroids

- Predict stress concentrations and/or local failure of irregular shape objects subject to static pressure loading
- 1/38-scale model of **Itokawa** selected for FE analysis using *NASTRAN*
- Pressure distribution from flow computations for $V = 20$ km/s and $P_{stag} = 30$ bar



- Compression factor of 1.5x on rocky outcrop, only 1.0x in the neck region
- Failure in tension likely to occur near the neck and rupture would occur at prominent surface features such as protrusions and depressions

Future Outlook

- Modeling of representative unit cells with defects, such as cracks and inclusions based on ground test characterization of meteorites.
- Development of scaling criterion from unit cells to asteroids
- Incorporate thermal/mechanical test results of meteorite samples into FE models.